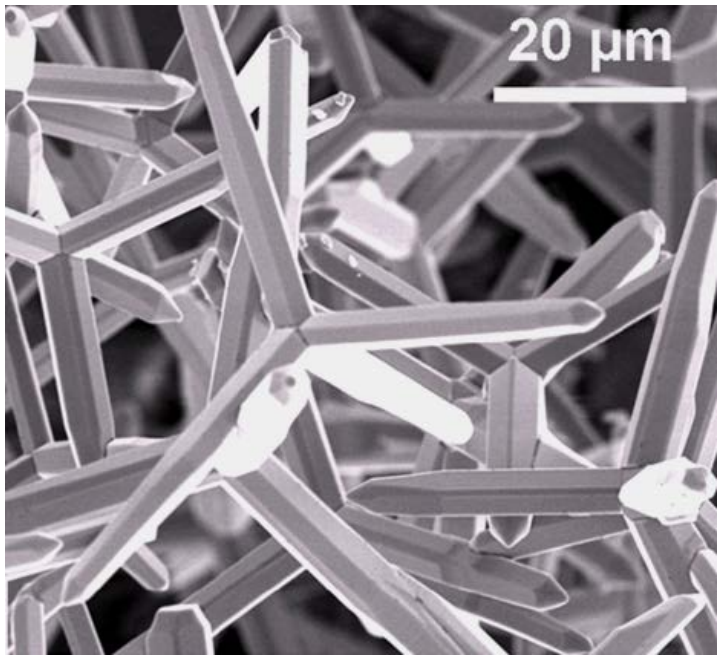
Christian-Albrechts-Universität zu Kiel

Forschungen zu Lösungsmittel und Biozid freiem Antifouling



Rainer Adelung

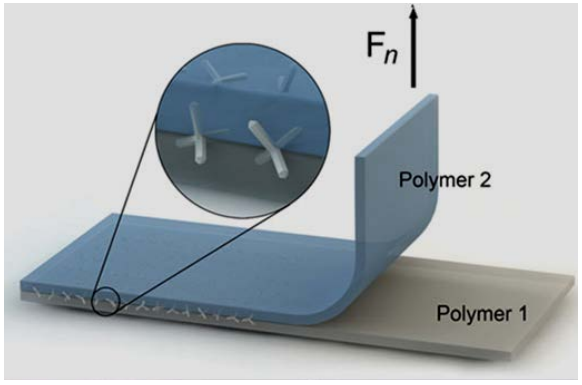
Institut for Materials Science -
Chair for Functional Nanomaterials

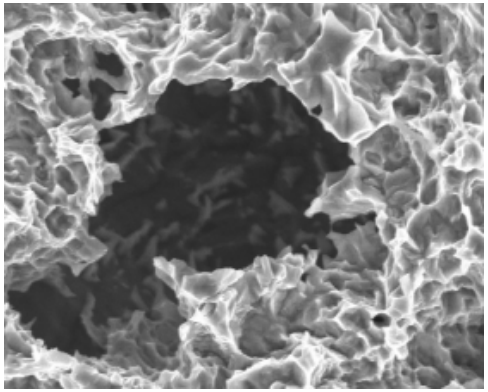
Otterndorf 2016

Christian-Albrechts-Universität zu Kiel

Content

- Biofouling / “Antifouling”
- Porous materials
- Porous metals for increased corrosion resistance and interlocking
- Porous ceramics + solvent free polymer
- Biocorrosion resistance





Nr. 5 | Nover

Editorial

Sehr geehrte Leserin,
sehr geehrter Leser,

Dr. Martina Baum

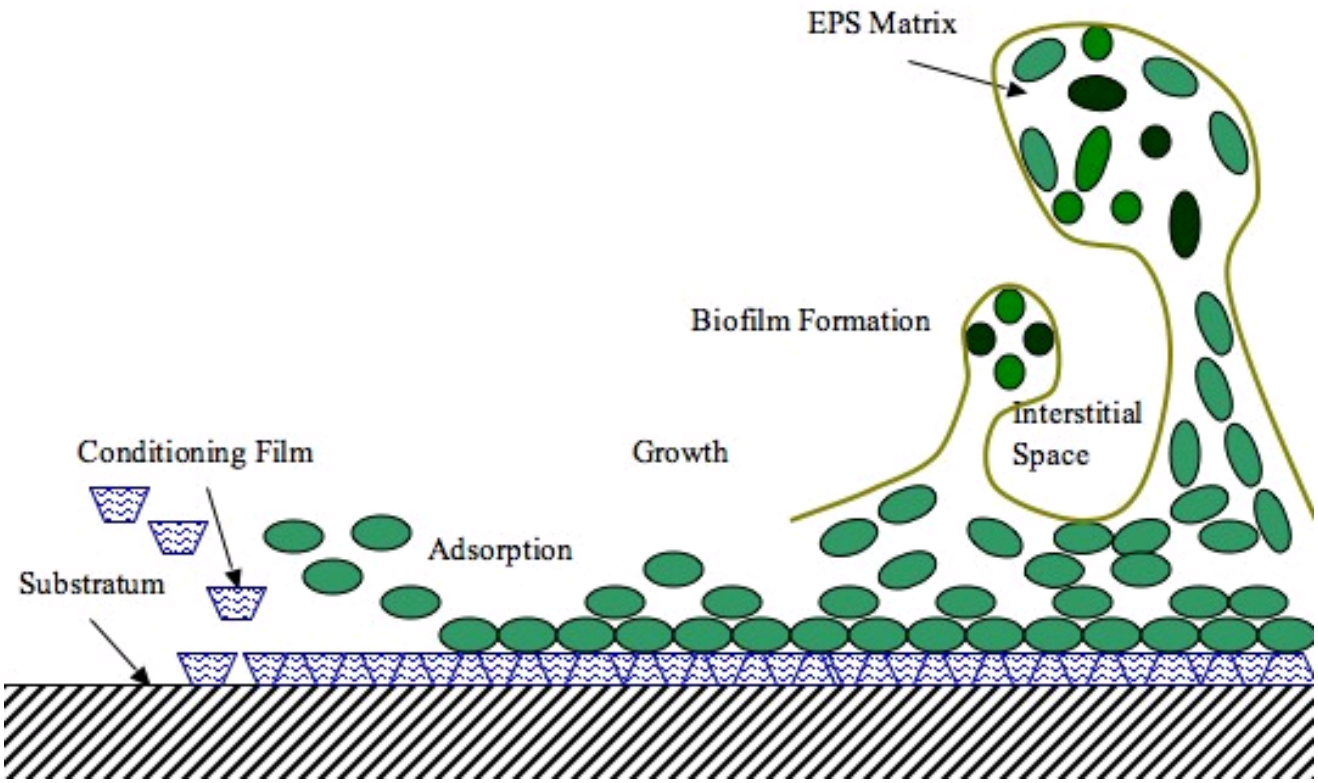
die Nanotechnologie ist eine Querschnittsdisziplin mit hohem Innovationspotenzial in vielen Bereichen. Dazu gehören auch die maritimen Technologien. Ein wichtiges Beispiel ist der Bewuchs von Schiffsrümpfen und anderen maritimen Bauwerken, der ökologisch wie ökonomisch ein enormes Problem darstellt. Bei Schiffen kann der Bewuchs zu einer Erhöhung des Strömungswiderstands um 20 % führen, was mit einer Erhöhung des Treibstoffverbrauchs von bis zu 40 % einhergehen kann. Nicht zu vergessen, dass

auf Flora un
Verschieder
Schiffslack
werden b
viele gu
sche Gr
weltfreun
anwendbaren Al
wandten Antifouli
Um dies erreich
Pfade beschritten unc
verwandten Antifouli
Der Einsatz von Nanc

Biofouling

Fotos: Dr. M. Baum, Gl. Ålbo, 2014

Biofouling



Wikipedia: Biofouling „microfouling“

Biofouling

„macrofouling“ Wikipedia (LimnoMar)

Biofouling

„macrofouling“ Wikipedia (LimnoMar)

„macrofouling“ Wikipedia (LimnoMar)

M. WIEGEMANN, & B. WATERMANN (2003):
Peculiarities of barnacle adhesive cured on non-stick surfaces. J. Adhesion Sci. Technol. 17(14), 1957–1977.

Biofouling

Acta Biomaterialia

Volume 6, Issue 7, July 2010, Pages 2690–2694

Open volume in bioadhesive detected by positron annihilation lifetime spectroscopy

Klaus Rätzke[a], Maja Wiegemann[b], Muhammad Qasim Shaikh[a], Stephan Harms[a], Rainer Adelung[a], Werner Egger[c], Peter Sperr[c]

[a] University of Kiel, Kaiserstr. 2, Kiel, Schleswig-Holstein, Germany

[b] MAReCOAT, Geversdorf, Germany

[c] BW University Munich, Munich, Germany

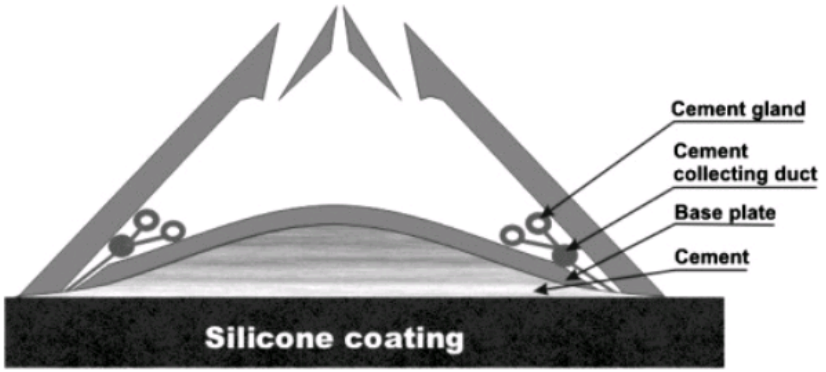


Fig. 1.
Scheme of a *Balanus* barnacle attached to a PDMS coating. There is multilayered cement between the concave-shaped baseplate and the substratum, the density decreasing towards the latter. The cement thickness on a specific coating type ranges between 0.5 and 2 mm [42]. Note that the penetration depth of the positrons into the cement is approximately 1 μm.

„macrofouling" Wikiped

M. WIEGEMANN, & B. WATERMANN (2003):
Peculiarities of barnacle adhesive cured on non-stick surfaces. J. Adhesion Sci. Technol. 17(14), 1957–1977.

Top Down porosity: Pore etching

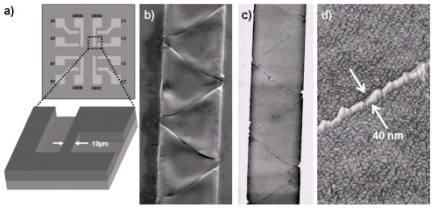
Holes & Analytics

2D

3D

-Impedance spectroscopy
-Solar cell (Cello)

Nat. Mat. 2004
Adv. Mat 2006
Small 2008
…



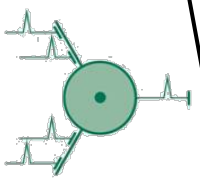
Porous materials

Bottom up

Top down

Battery research
-Li-ion battery anodes
(500+ cycles; 3000+ mAh/g)

FOR 2093
memristive



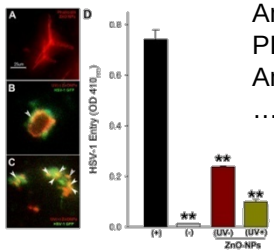
FTS

ME-Sensors
SFB 855

biomagnetic sensing KIEL NANO SCIENCES

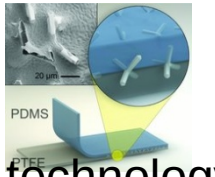
Adv. Mat 2012
Adv. Mat 2013

Antiviral research
Toxicology



Antiv. Res. 2011
PLOS 2012
Antiv. Res. 2013
…

Polymer composites
-SFB 677
-self reporting composites
-advanced interconnection technology



Technology transfer (BMWi)
-Polyramic
-Uraphit
Wind energy, antifouling…

Flexible ceramic
-fast UV sensor
-Aerographite

Adv. Mat 2012
Adv. Mat 2014
Adv. Electron. Mat. 2015

Top Down porosity: Pore etching

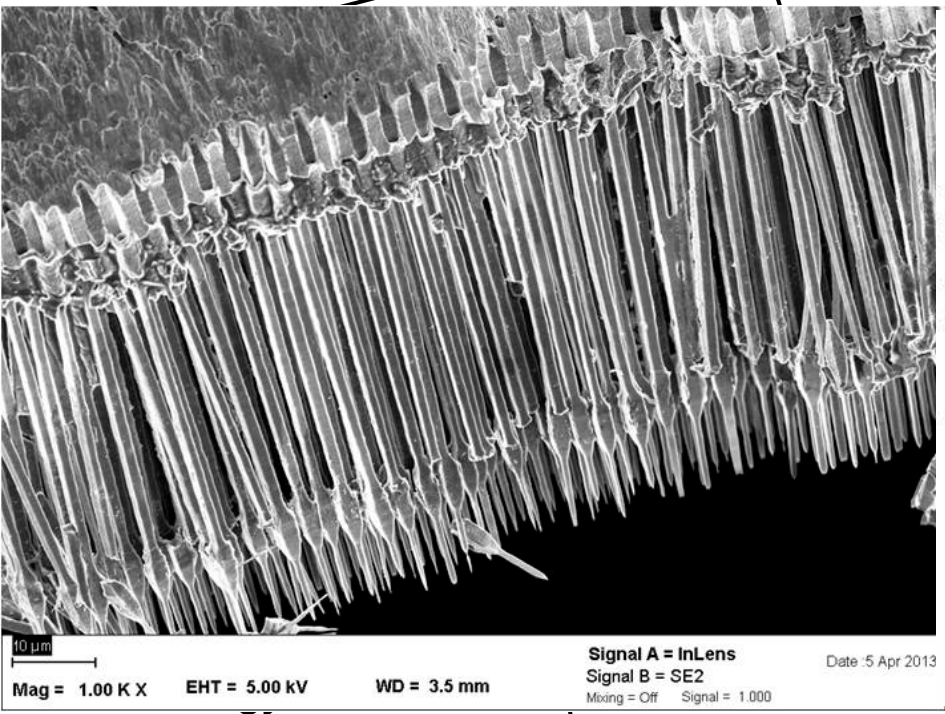
Christian-Albrechts-Universität zu Kiel

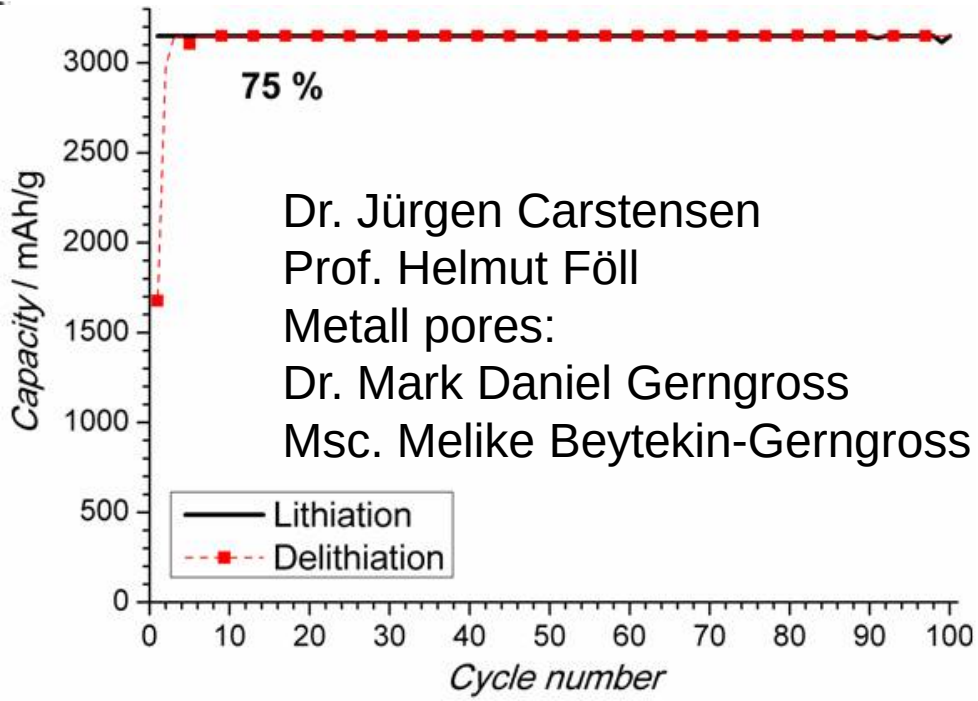
Holes & Analytics

2D

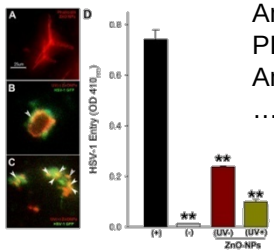
3D

-Impedance spectroscopy





Dr. Jürgen Carstensen
Prof. Helmut Föll
Metall pores:
Dr. Mark Daniel Gerngross
Msc. Melike Beytekin-Gerngross



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PLOS 2012
Antiv. Res. 2013
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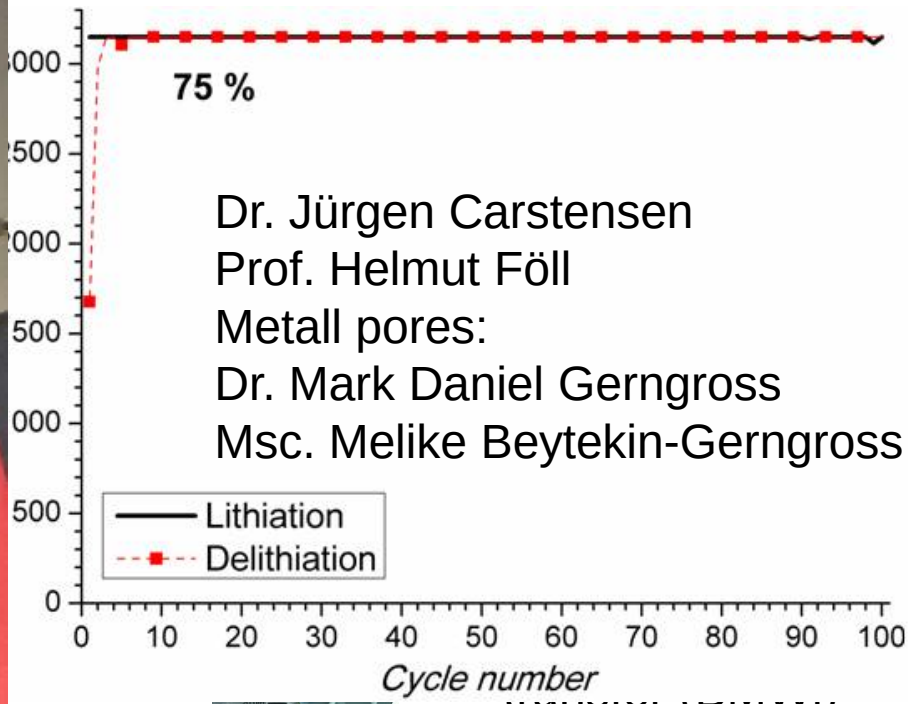
Top Down porosity: Pore etching

Holes & Analytics

-Impedance spectroscopy



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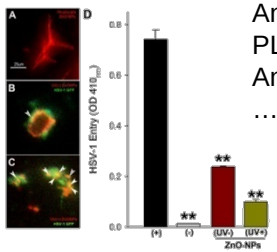

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Adv. Mat 2014
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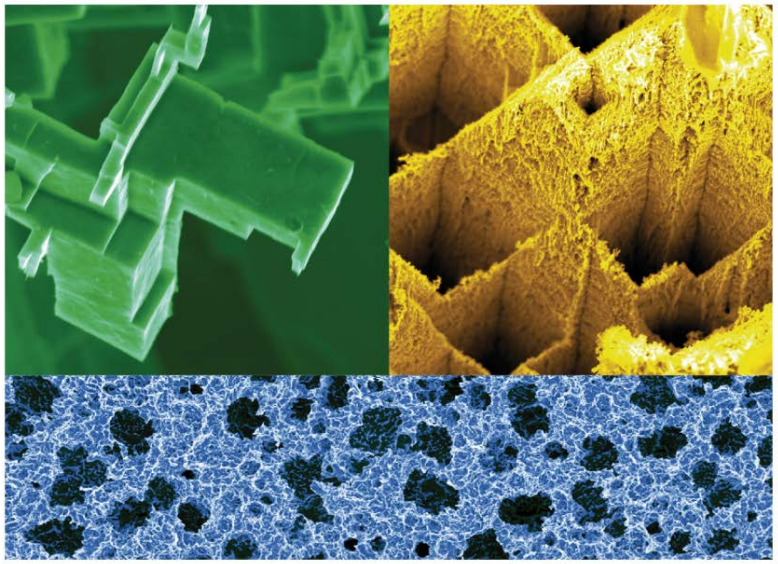
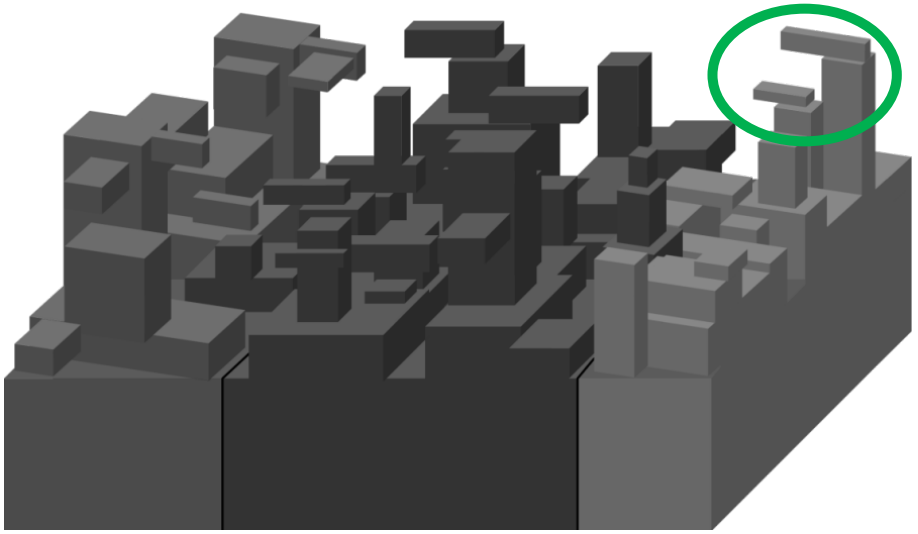
Metal pore etching: Nanoscale Sculperting



example: Al / Al alloys



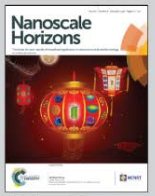
Nanosculptured surfaces from Prof. Rainer Adelung's Group for Functional Nanomaterials, Institute for Materials Science, Kiel University, Germany

Making metal surfaces strong, resistant, and multifunctional by nanoscale-sculpturing

Surfaces are the crucial and limiting factor in nearly all metal applications, especially when technologically relevant alloys are employed. Insufficient surface properties on the nano- and microscale of metals determine, *e.g.* metal–polymer composite stability, implant biocompatibility, or corrosion resistance. Conventionally prepared surfaces contain various element mixtures and complex microstructures.

In contrast, the here described novel nanoscale-surface sculpturing based on semiconductor etching knowledge turns surfaces of everyday metals into their most stable configuration.

As featured in:



See R. Adelung *et al.*, *Nanoscale Horiz.*, 2016, **1**, 467.

ROYAL SOCIETY OF CHEMISTRY

rsc.li/nanoscale-horizons

Registered charity number: 207890

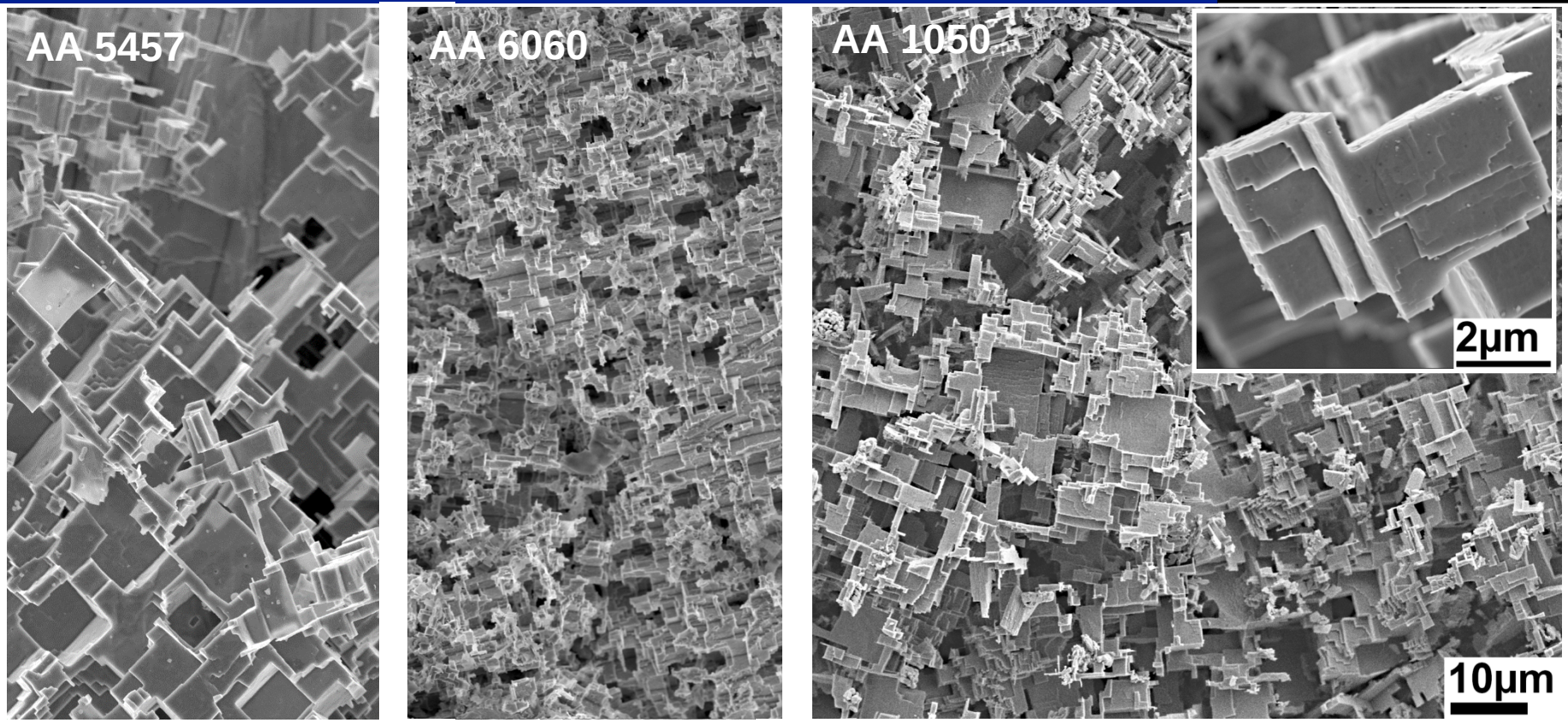
hook-like structures:

M. Baytekin-Gerngross, M. D. Gerngross, J. Carstensen and R. Adelung, *Nanoscale Horizons*, 2016, **1**, 467-472

mechanical interlocking when enclosed by other materials

INTERNATIONAL ALUMINIUM JOURNAL
SPACE DAILY your portal to space
innovations report Forum für Wissenschaft, Industrie und Wirtschaft

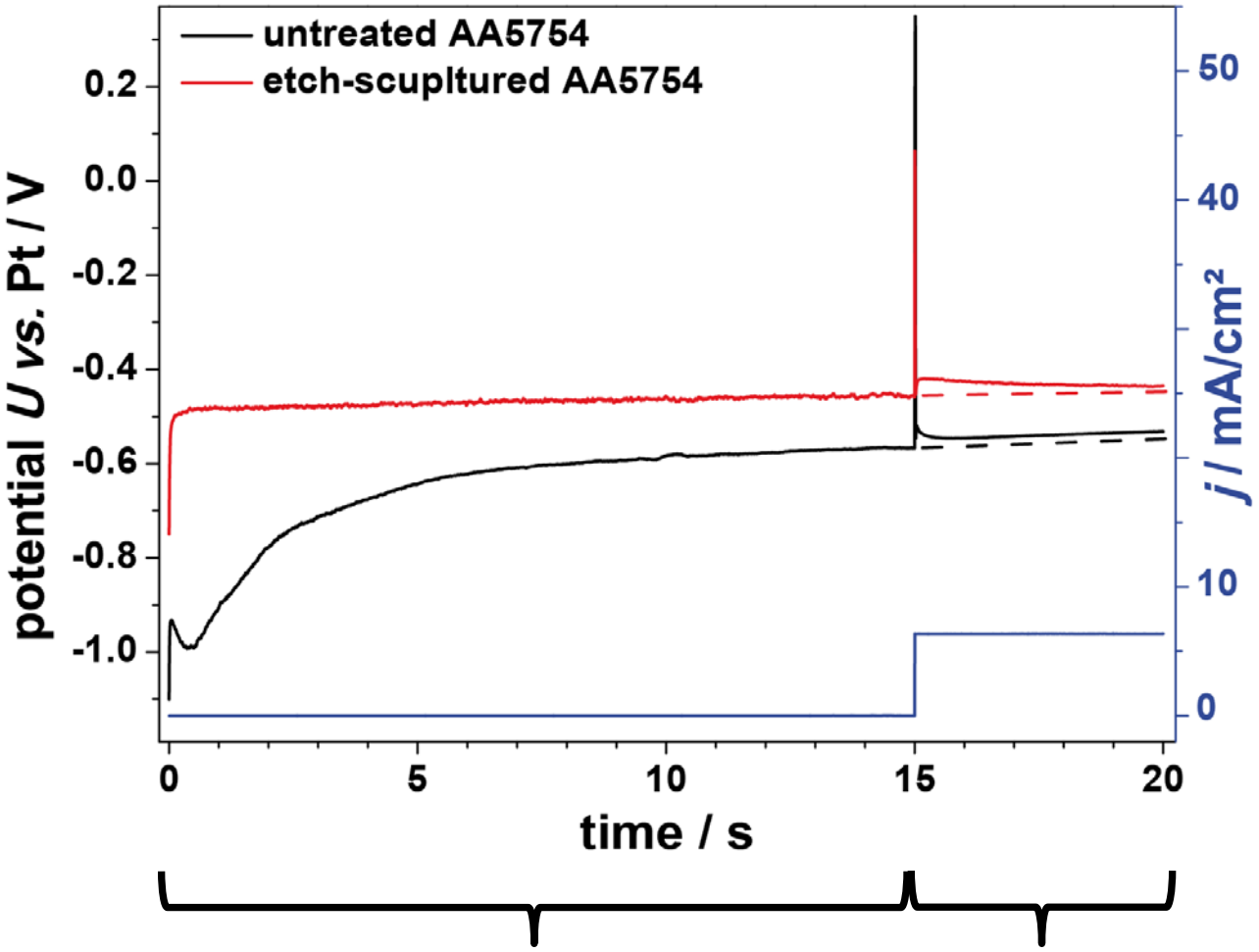
Metal pore etching: Nanoscale Sculpturing



sculpturing via crystallographic etching → remain of most stable surface elements → higher corrosion resistance

further Al alloys possible, already tested with multitude of alloys

Metal pore etching: Nanoscale Sculpturing



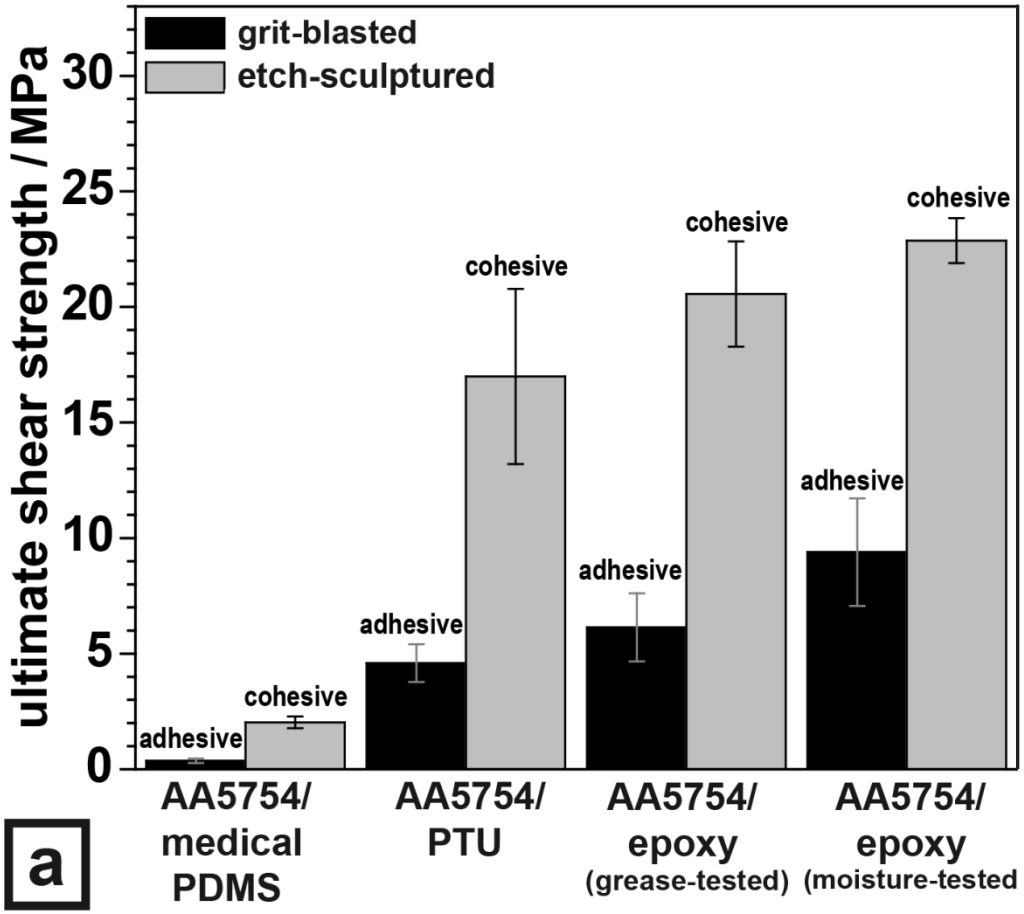
higher OC voltage

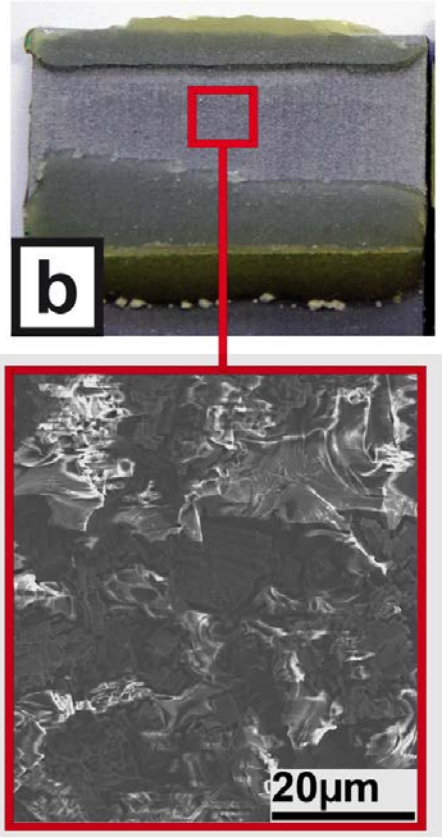
→ **higher** corrosion resistance

flat line in OC

→ electrochemically **stable** surface

Metal pore etching: Nanoscale Sculpturing





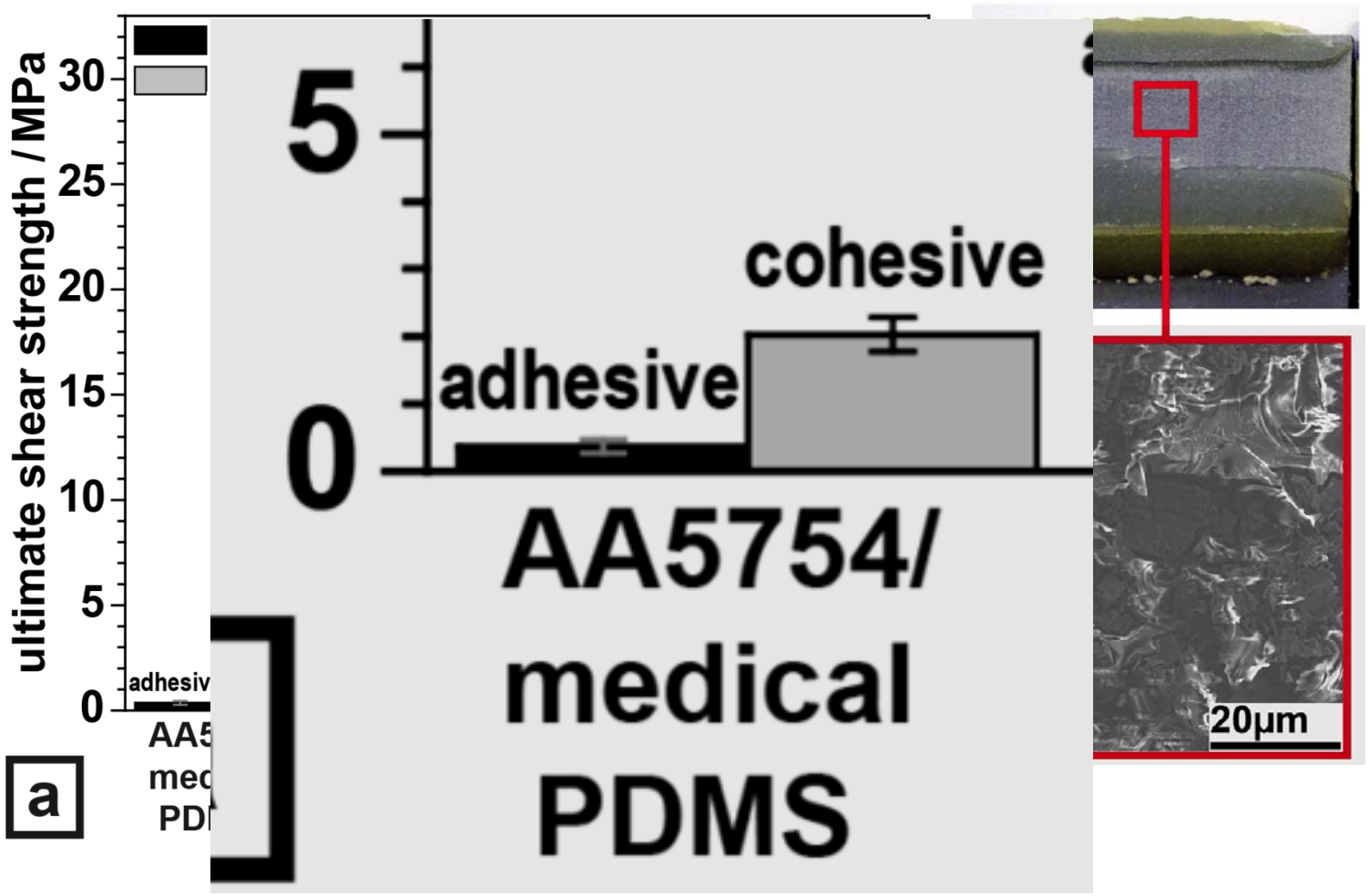
sculptured surfaces:

only **cohesive** failure

joints to sculptured surfaces **unaffected** by grease, moisture etc.

mechanical properties of polymer **limiting** for joint strength

Metal pore etching: Nanoscale Sculpturing



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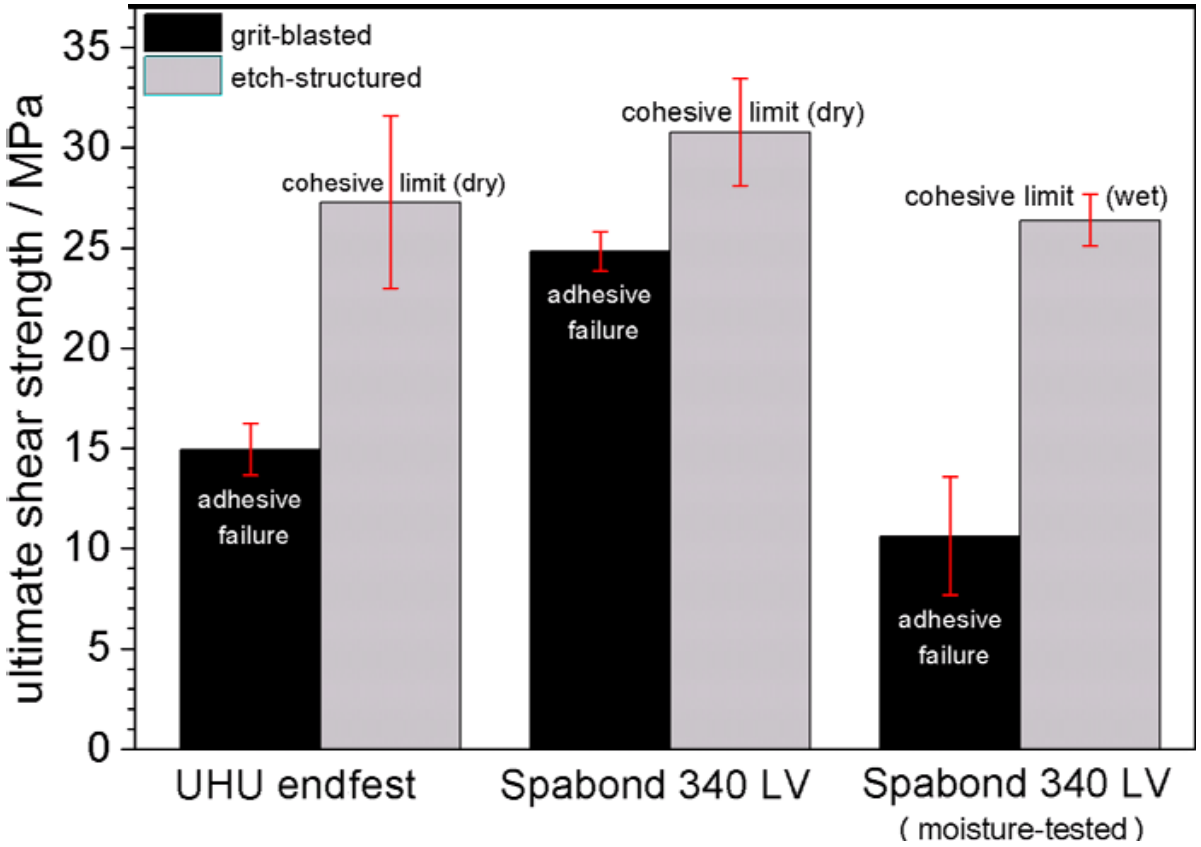

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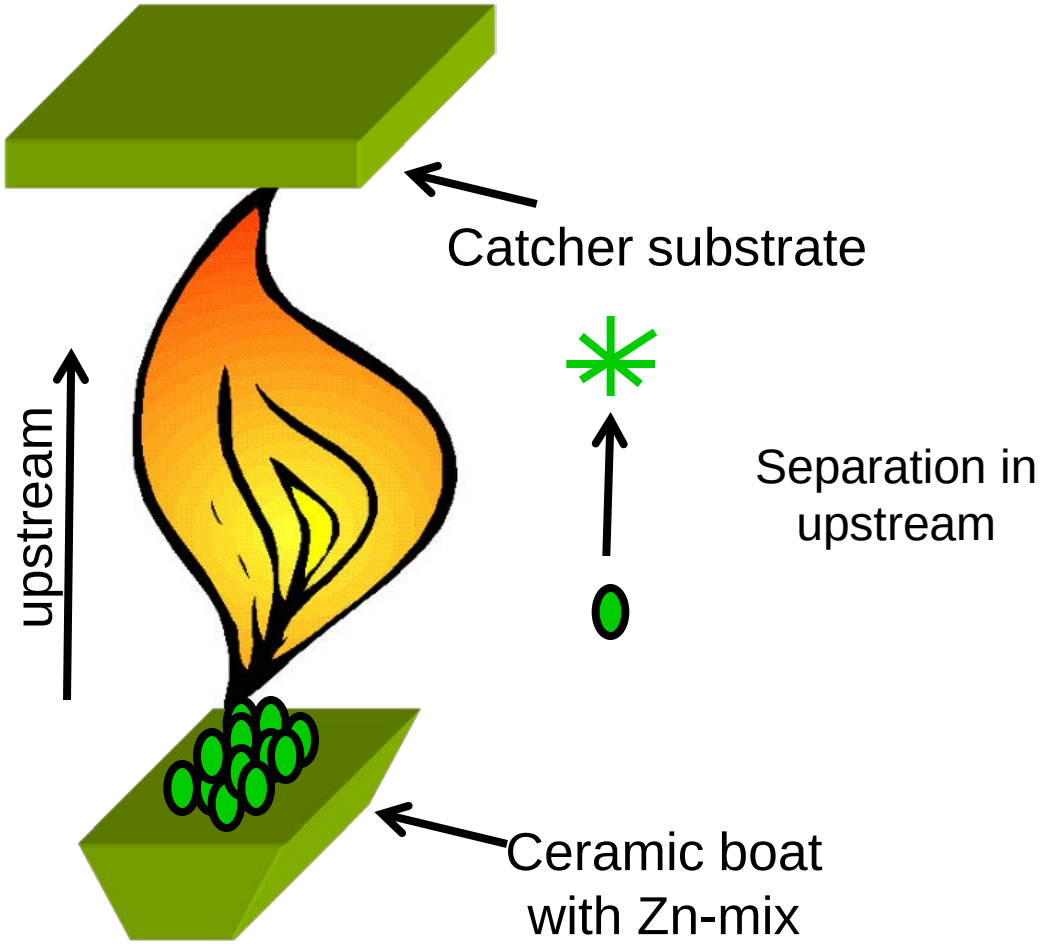
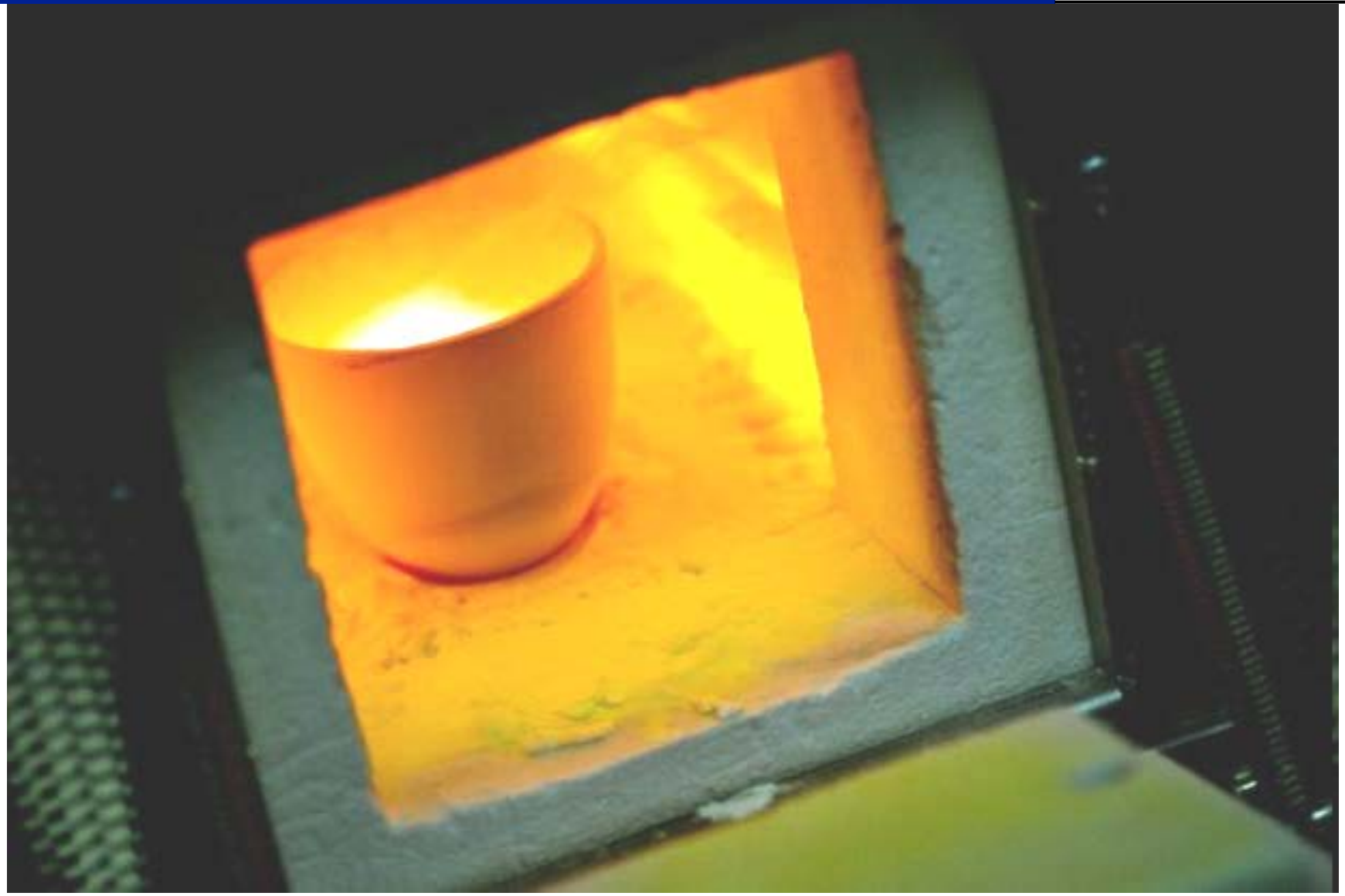
Flame transport synthesis



Upscaling is possible

Flame transport synthesis



Upscaling is possible

Flame transport synthesis

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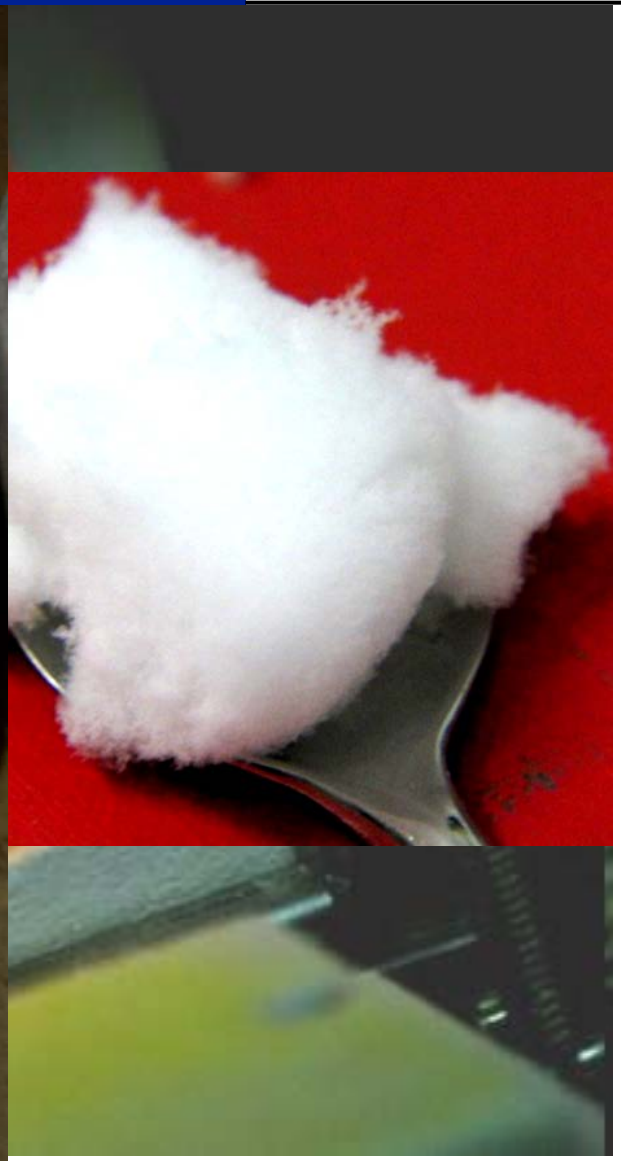
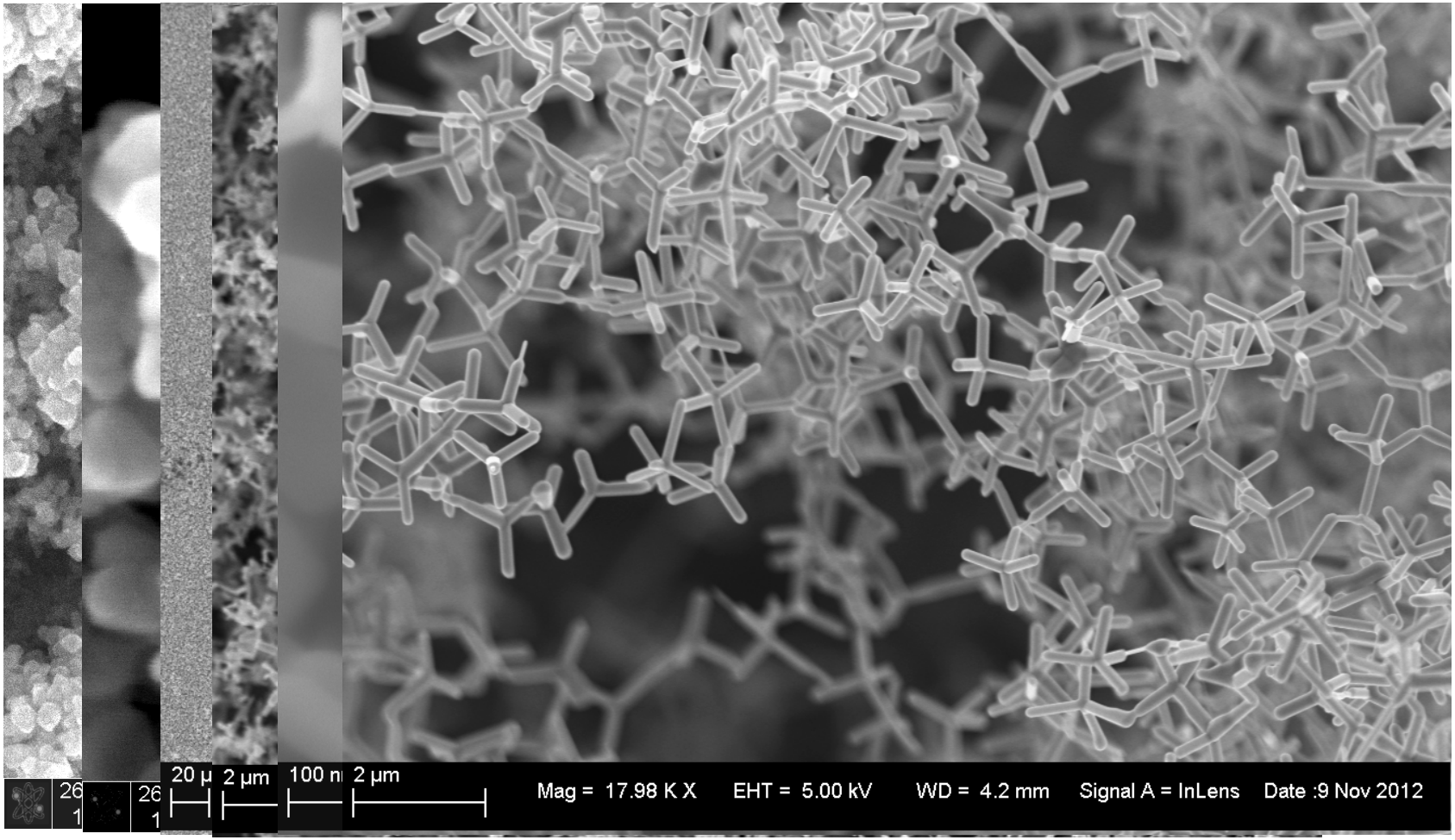
Flame transport synthesis



Upscaling is possible

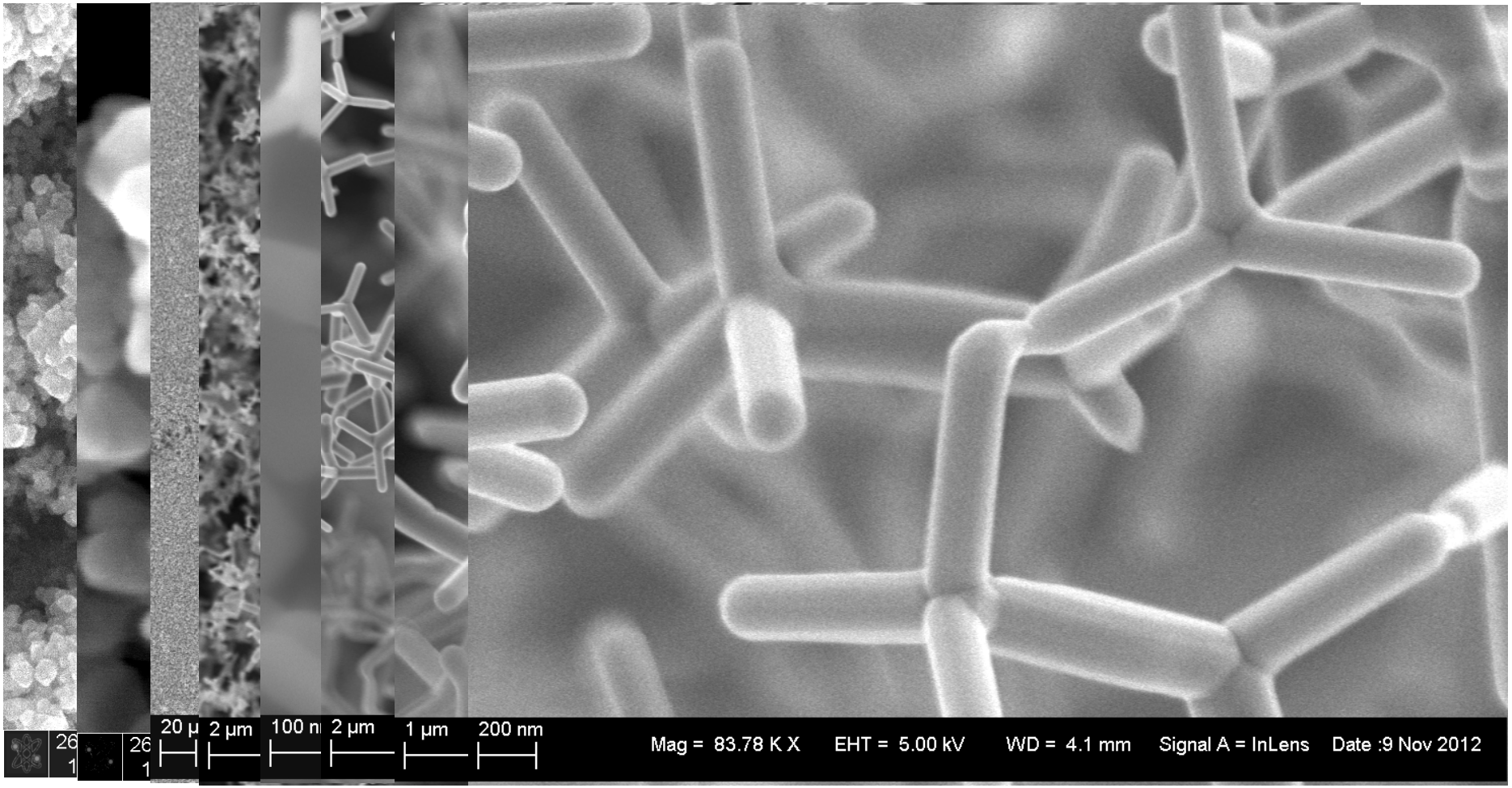

Upscaling with University startup
FUMT R&D
FUMT R&D Functional Materials GmbH

ZnO Nanostructures (variation for smaller structures)



Various shapes possible: No nanoparticles!: Nanostructured microparticles…

ZnO Nanostructures
(variation for smaller structures)



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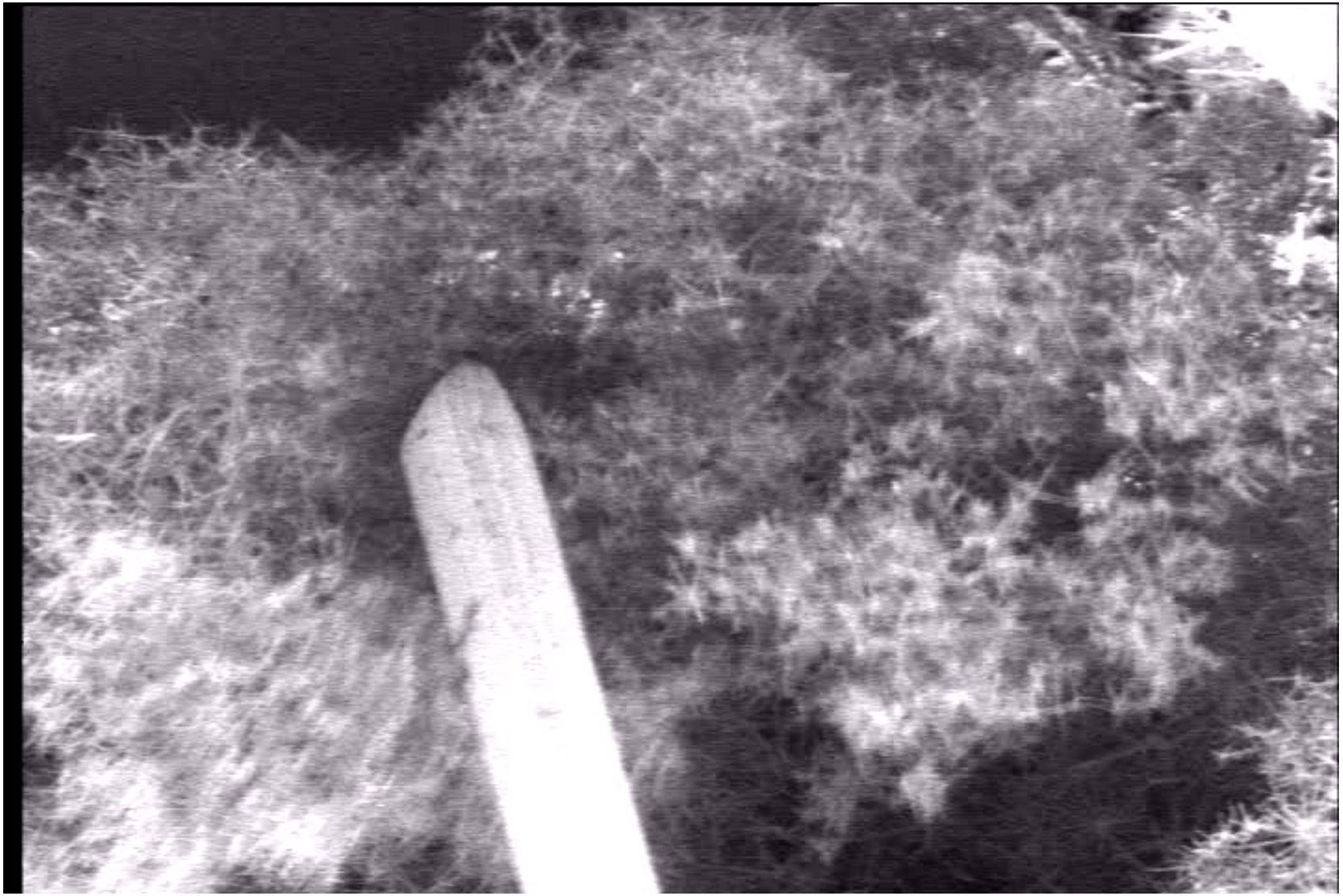
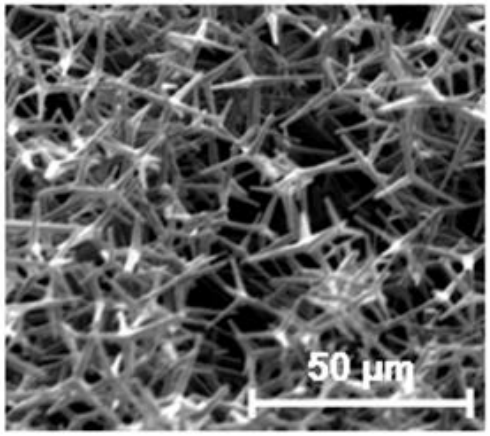
ZnO Nanostructures (variation for smaller structures)

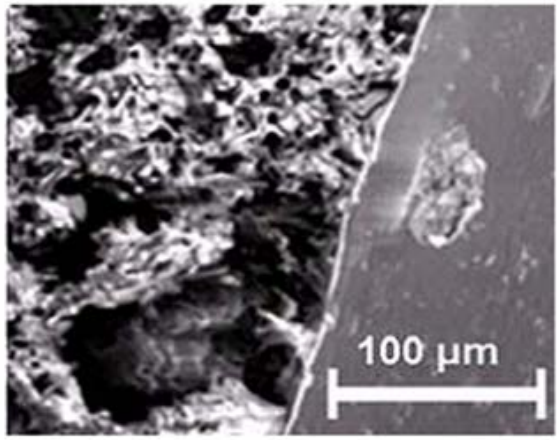
Various shapes possi anostructured mic

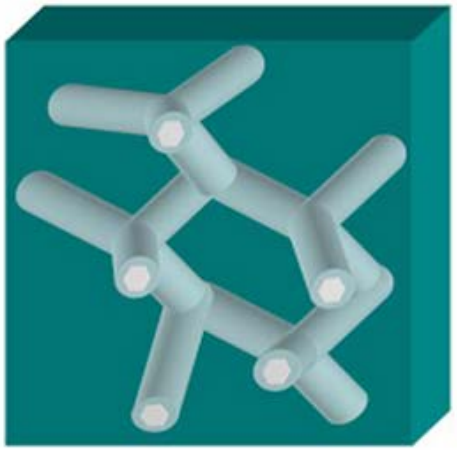
Flexible nanostructure based ceramics

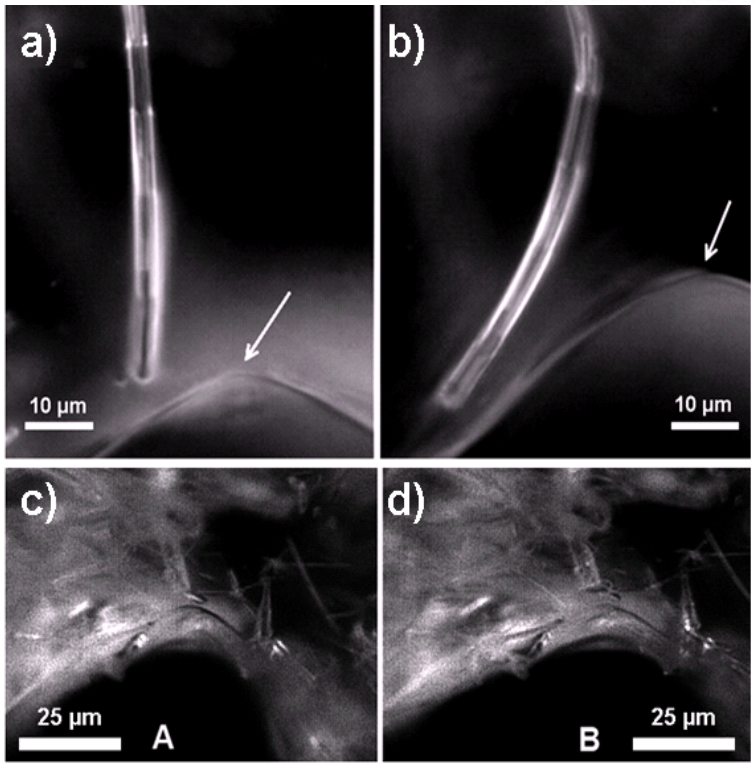


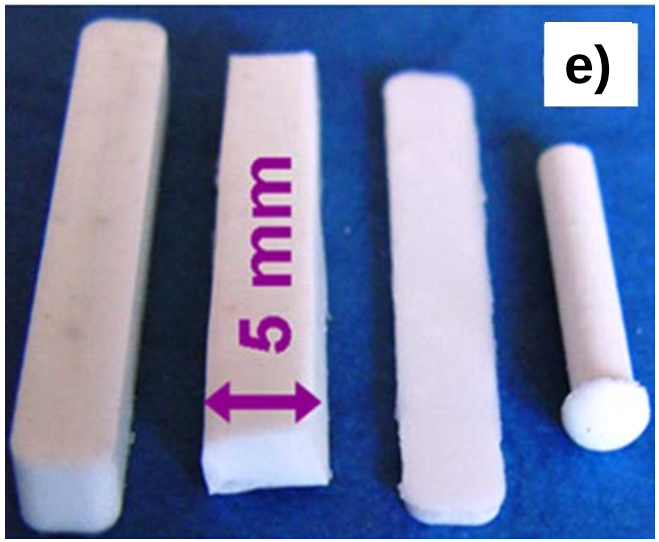
Composite materials: PDMS/ZnO





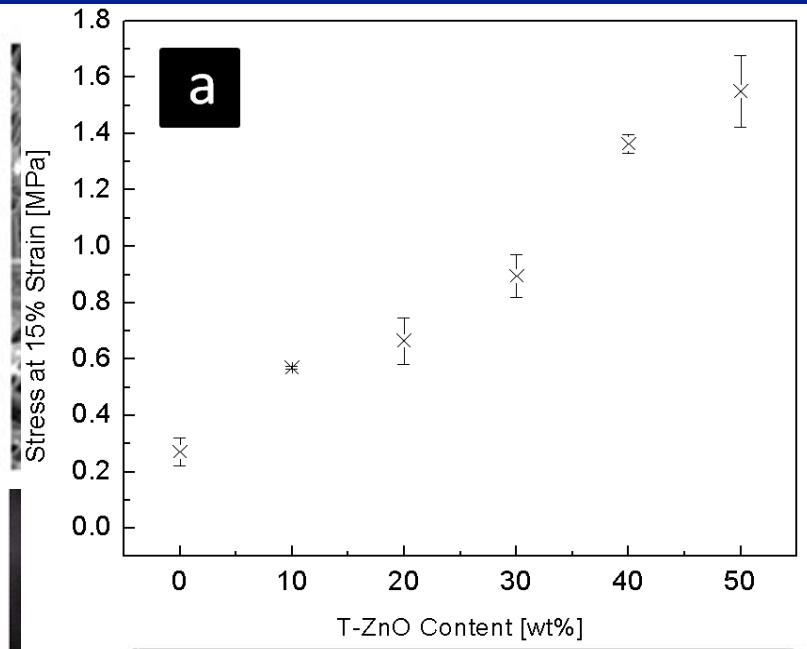


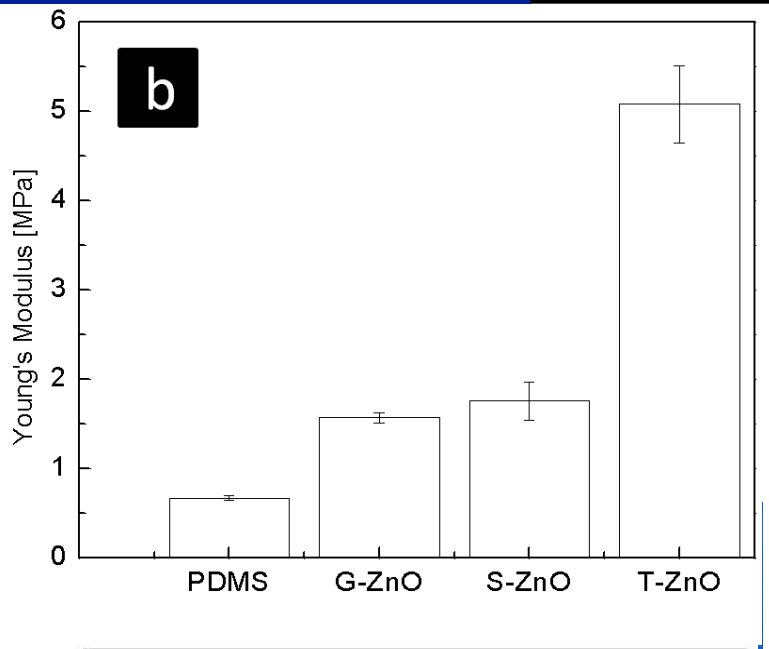


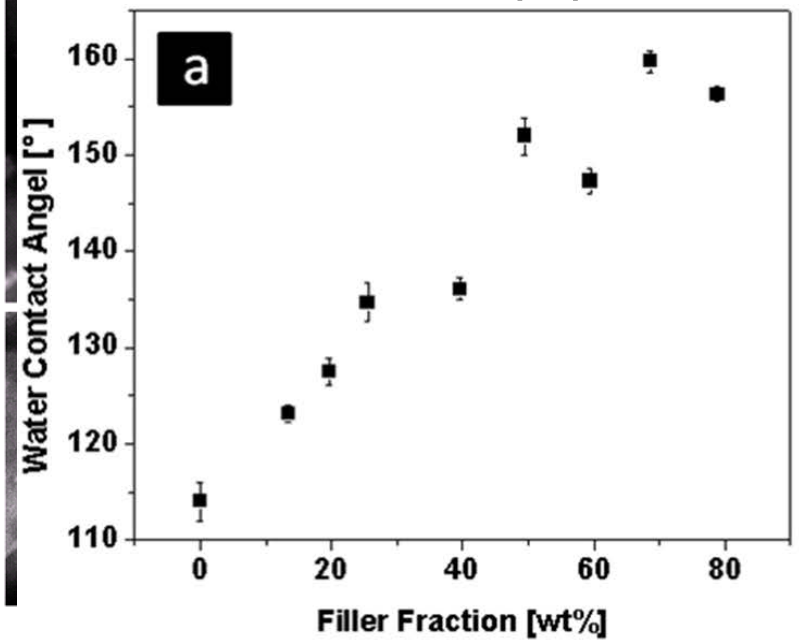


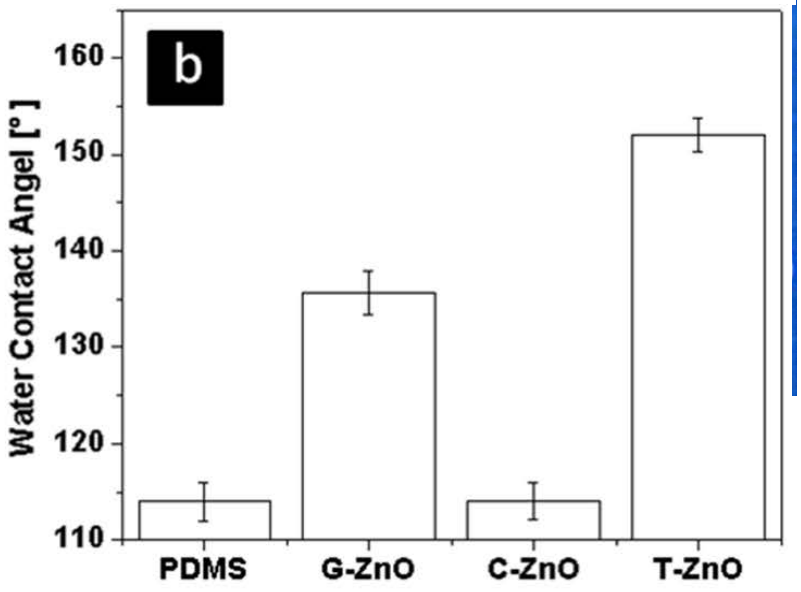
- Energy uptake during cracking
- Fracture supressed!

Composite materials: PDMS/ZnO

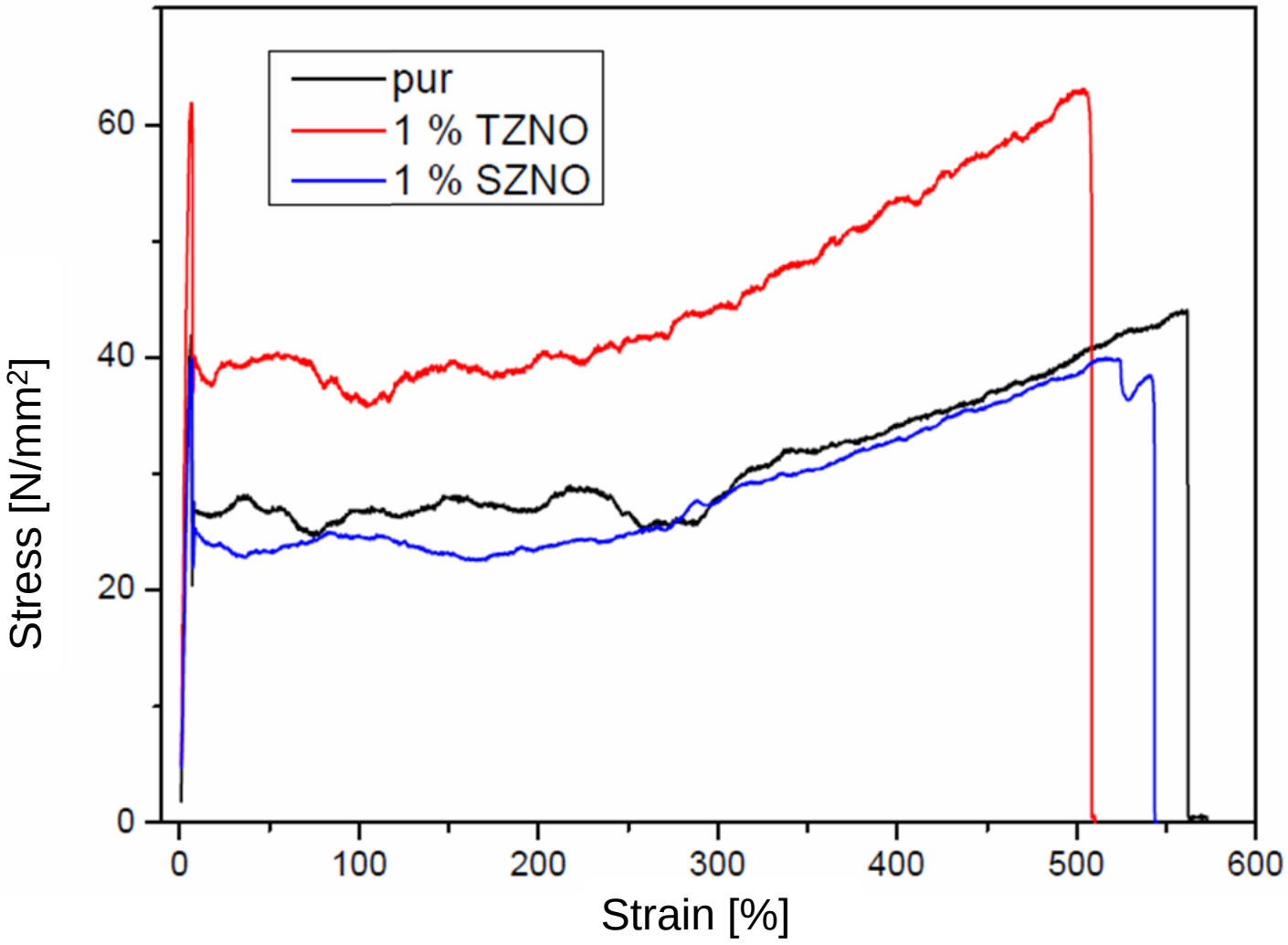






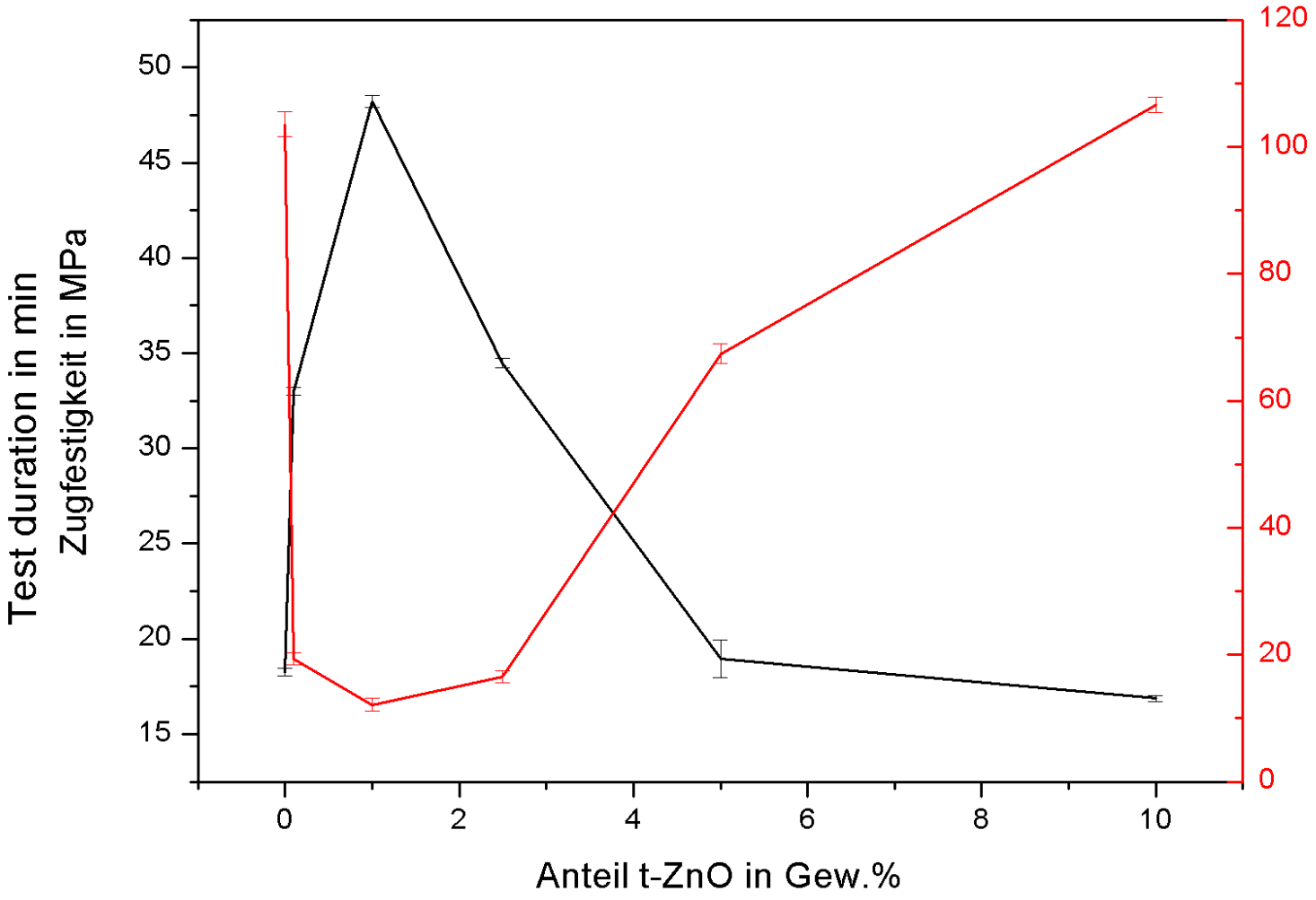


Tetrapod filled conventional polymers



-„Simple“ polymers: same tensile strength @ 30% reduced weight
-Epoxy ~ performance of high performance glues

Tetrapod filled polymers “Polyramic”:

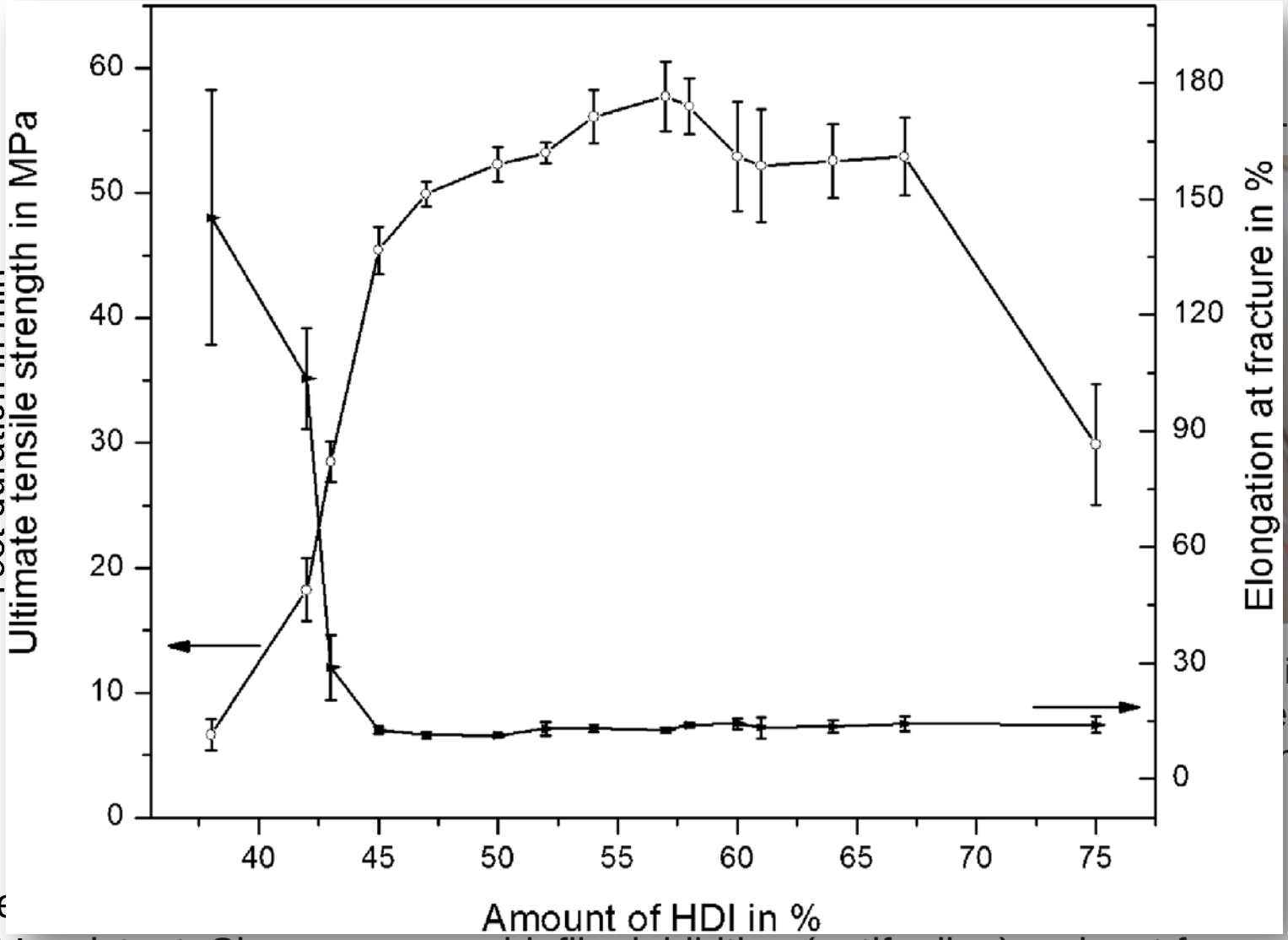


KL-WEA (BMWi):

et impact resistance
nes vs.
ercial products

New properties by compound materials:
UV resistant, Shape memory, biofilm inhibiting (antifouling), solvent free…

Tetrapod filled polymers “Polyramic”:



-WEA (BMWi):

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Ne

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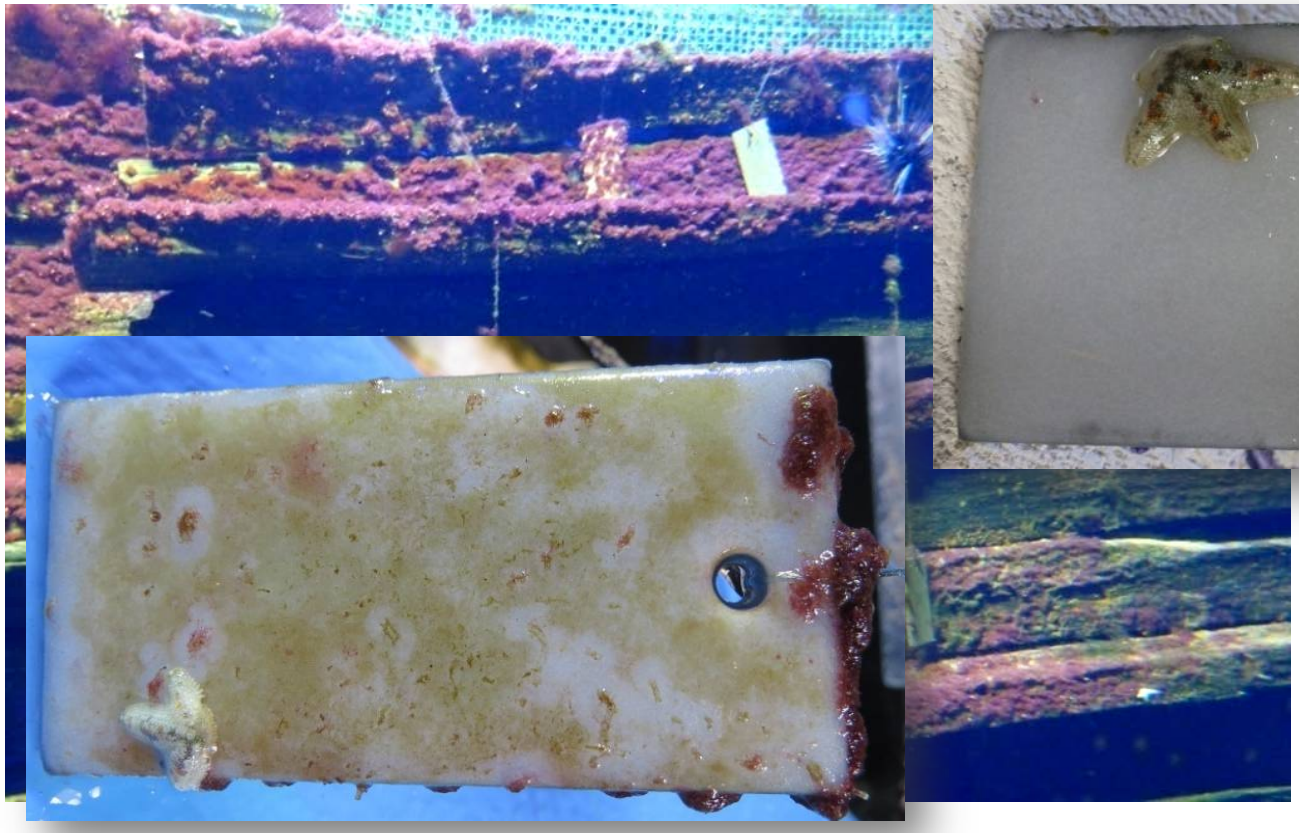
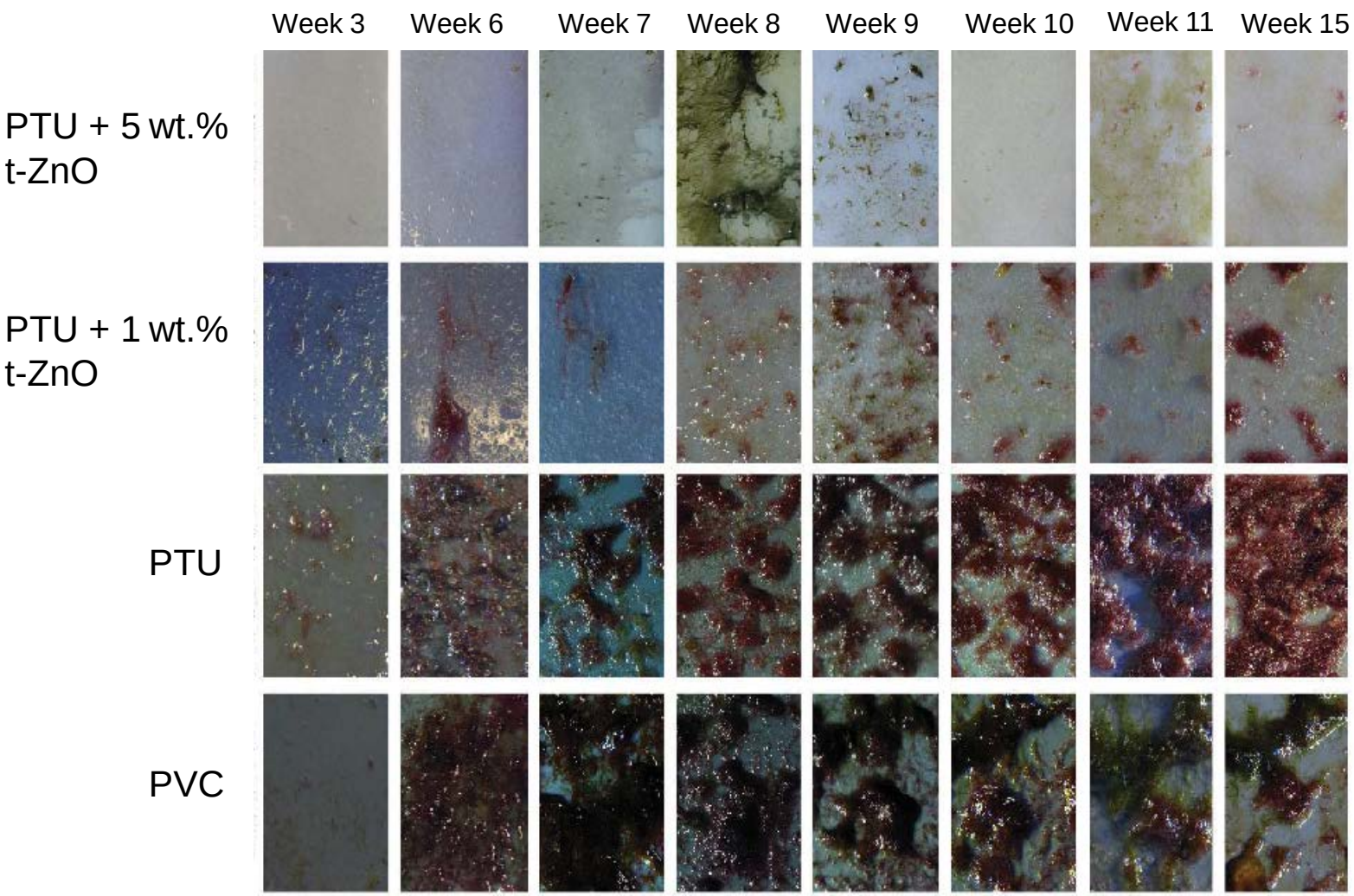
Biocorrosion resistance



PTU + 5% tZnO

Pacific water tank Geomar Aquarium Kiel

Biocorrosion resistance



I. Hölken, M. Hoppe, Y. K. Mishra, S. N. Gorb, R. Adelung & M. Baum
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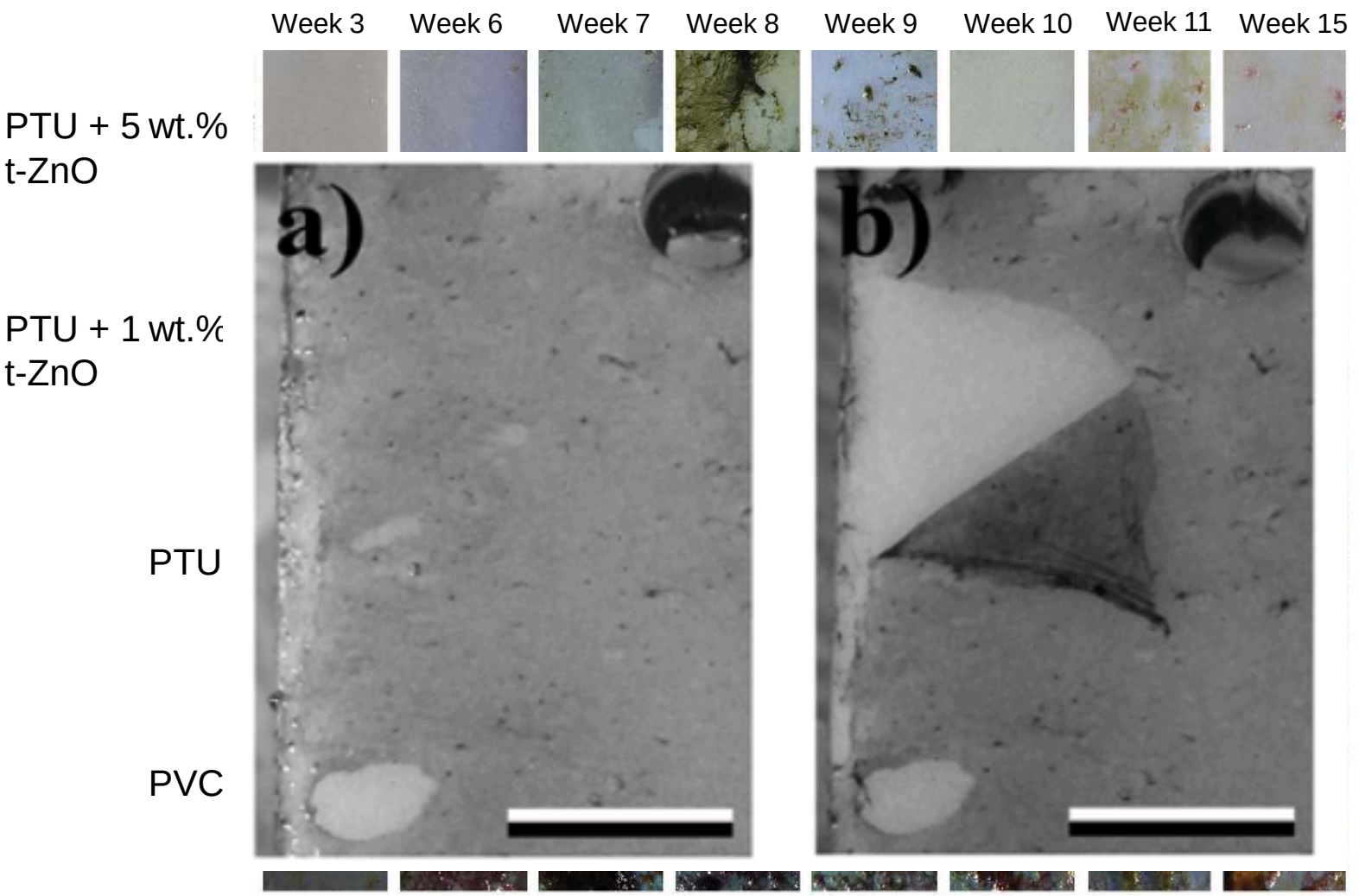
Biocorrosion resistance



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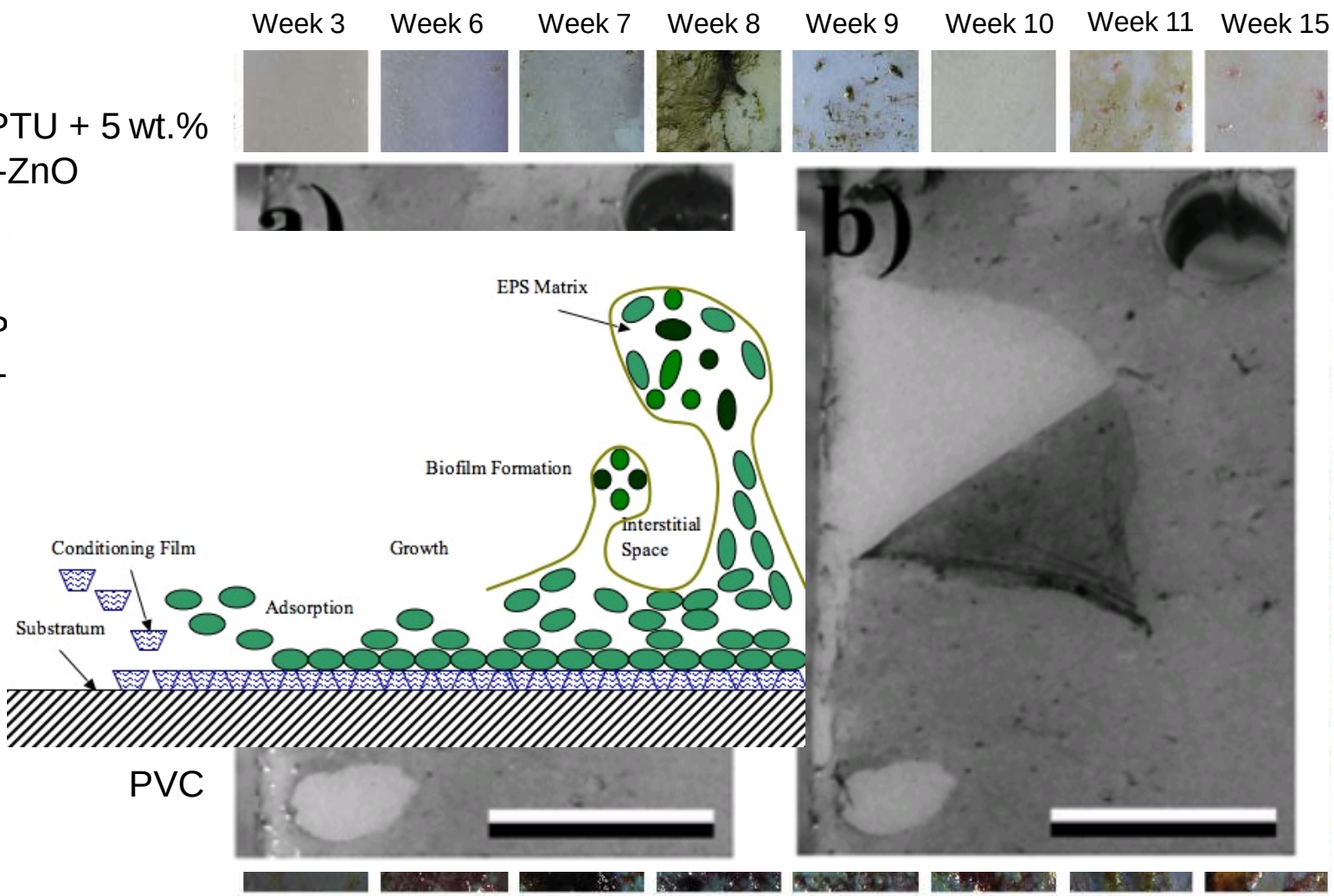

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